1. Using the point charge model, write the general expressions for the components of the EFG tensor for the central atom X in a XYₙ molecule for the following molecular geometries:

   a) in-plane bent (H₂O geometry), assume arbitrary bond angle;
   b) trigonal bipyramidal;
   c) octahedral

2. The quadrupolar coupling constants C_Q of the three nonequivalent vanadium sites in Cs₂V₄O₁₁ were determined experimentally, and are 1.9, 2.6, and 2.4 MHz. From the X-ray crystal structure it is known that two sites are distorted tetrahedral pyramids, and the third one is with octahedral coordination. Can you attribute the experimental C_Q to specific coordination environments? Explain.

3. It was found that the length of the ⁵¹V π/2 excitation pulse in neat VOCl₃ liquid is 6 μs. What are the lengths of the ⁵¹V pulses required to excite i) the central transition and ii) all the satellite transitions in a solid K₃VO₄? Assume the other experimental parameters are the same.

4. Write the Hamiltonian and sketch an energy level diagram for a spin- 7/2 nucleus. Describe the effects of the first- and second- order quadrupolar interaction on the energy levels.

5. Sketch a static NMR spectrum of central and satellite transitions of a spin- 7/2 solid in the presence of the quadrupolar and chemical-shielding anisotropy interactions. Assume the solid comes as a powder and there is one nuclear site. Label the individual transitions and the salient spectral features.

6. Write the matrix representations for the basis set angular momentum operators  \( \hat{I}_z, \hat{I}_x, \hat{I}_y, \hat{I}_+, \hat{I}_- \)

7. Write the matrix representation of the rotation operator  \( \hat{R}_z(\varphi) \) for a spin-3/2 nucleus.

8. Suppose you have an ensemble of nuclear spins-3/2 prepared so that your initial density operator \( \rho(0) = I_x \). Write the matrix form of the density operator after you applied a radiofrequency pulse with a phase \( z \) and a flip angle of \( \pi/2 \). What does this matrix correspond to?